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AUTOTRANSFORMER TAP CHANGING CONNECTION

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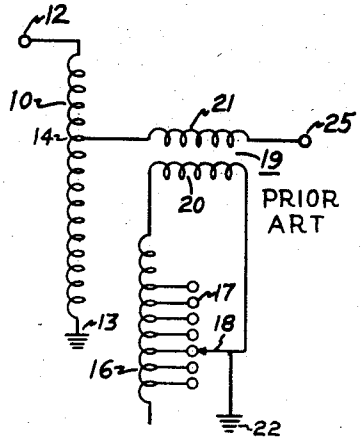


Fig. 1.

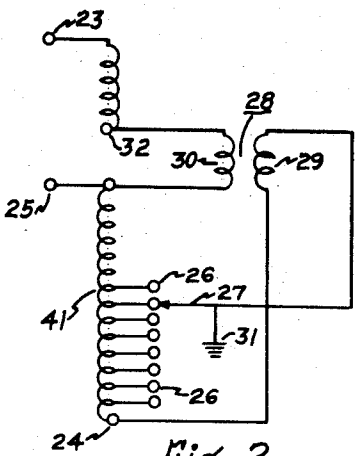


Fig. 2.

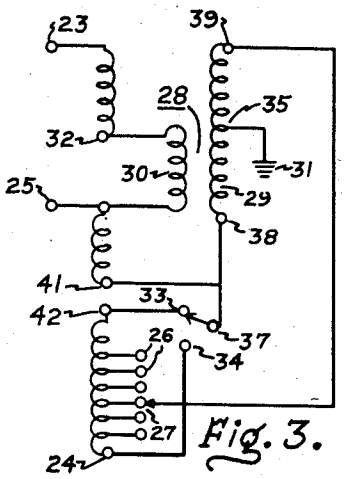


Fig. 3.

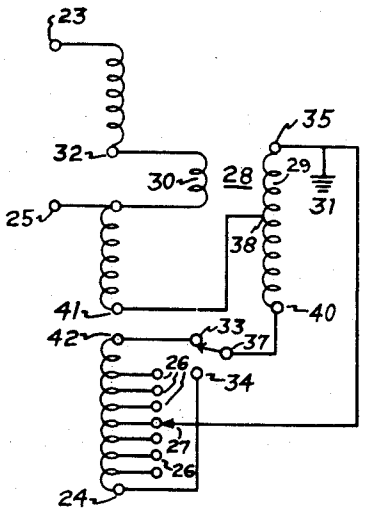


Fig. 4.

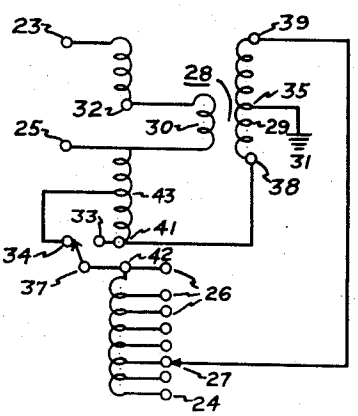


Fig. 5.

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AUTOTRANSFORMER TAP CHANGING CONNECTION

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16 Claims. (Cl. 323—57)

My invention relates to autotransformers, and more particularly to a tap changing connection for use with an autotransformer while under load. Regulation of the output voltage of a transformer while under load is quite often referred to as load ratio control, and this is customarily accomplished by means of a special tap changing switch. My invention is particularly directed to single phase or three phase grounded Y autotransformers with load ratio control of the low voltage side.

Since it is desirable that any voltage regulation of a transformer should be able to take place while the transformer is under load it is necessary to design special tap changing switches that will withstand the high current and voltage rating required. However, the voltage to be regulated is often of such a magnitude that it is more economical to isolate the tap changing switch from the transformer windings by means of a series transformer, than to provide a switch having adequate insulation. A series transformer comprises a core separate from the main transformer core, with a primary and secondary winding. Variable excitation for the series transformer is derived from a tapped portion of a separate winding (known as a tap winding) of the main transformer. In the case of an autotransformer a separate tap winding is connected through the tap changing switch to the primary of the series transformer. The secondary of the series transformer is connected in series with the low voltage winding of the autotransformer. In this way the voltage applied to the primary winding of the series transformer is regulated at a low auxiliary potential and then transferred into the relatively higher potential represented by the low voltage side of the autotransformer which is thus raised or lowered by the required amount. An additional advantage in using a series transformer is that the voltage and current requirements of the tap changing switch may be chosen to give optimum operating conditions for any particular switch. The choice of the switch voltage of course determines the appropriate turn ratio of the series transformer.

It is evident then, that the use of a series transformer in load ratio control has the advantage that the tap changing switch is isolated from the line potential, and also that by proper selection of the turn ratio of the series transformer the optimum voltage and current conditions can be obtained for a particular switch. However this type of circuit has the disadvantage that the series transformer must be rated at a relatively high capacity since its secondary winding must carry the current of the low voltage side of the autotransformer. In fact manufacturers design such series transformers to operate at the full k.v.a. of regulation, which is equal to half the percentage voltage regulation required, multiplied by the rated k.v.a. of the autotransformer. The cost of the voltage regulating equipment is consequently quite high since such a highly rated series transformer is required. In addition the series transformer has high ohmic and reactive losses, and it may be so bulky as to be incapable

of fitting into the same tank as the main transformer thus necessitating an auxiliary tank.

It is therefore the object of my invention to provide in combination with an autotransformer a voltage regulation circuit which utilizes a series transformer rated at much less than the k.v.a. of regulation.

A further object is to provide for regulating the low voltage side of a grounded neutral autotransformer by means of a series transformer rated to carry only that fraction of the k.v.a. of regulation which corresponds to the ratio of high voltage current to low voltage current.

In accordance with my invention I connect a tap winding in series with the common winding of the autotransformer through a tap changing switch. This tap winding is used to supply variable excitation to the primary winding of a series transformer. In order to compensate for the increase or decrease in turns in the autotransformer common winding as a result of the action of the tap changing switch, thereby to maintain constant flux in the autotransformer core, I connect the secondary winding of the series transformer in series with the series winding of the autotransformer. Thus the insulation rating of the series transformer need be no greater than formerly, and the current rating may be reduced to that of the series winding.

In one form my invention is disclosed embodying a 1:1 ratio series transformer. However I also disclose how my invention may be utilized such that the series transformer need not have a 1:1 ratio, and the common winding may connect to the tap winding, either directly or through the series transformer primary.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a circuit diagram showing the prior art connectons for voltage regulation of the low potential side of an autotransformer;

Fig. 2 is a circuit diagram of one autotransformer arrangement according to my invention;

Fig. 3 is a circuit diagram of another autotransformer arrangement according to my invention;

Fig. 4 is a circuit diagram of a modified form of the autotransformer arrangement of Fig. 3; and

Fig. 5 is a circuit diagram of another modification of the autotransformer arrangement of Fig. 3.

With reference to Fig. 1, I have shown an autotransformer **10** comprising a series winding **12—14**, and a common or low voltage winding **14—13**. The high voltage input of the autotransformer is thus across points **12** and **13**. In accordance with accepted practice, in order to regulate the low voltage side of the transformer, an additional winding **16**, on the main autotransformer core, is provided with a multiplicity of taps **17** which comprise the stationary contacts of a tap changing switch having a movable contact arm **18**. A series transformer **19** is provided having a primary winding **20** in series with winding **16** and a secondary winding **21** in series with the common winding **14—13** of the autotransformer. The low voltage output of the autotransformer is thus across points **13** and **25**. A ground connection is made as at **22** to the tap changing switch arm **18**. By means of the tap changing switch, winding **16** is used to regulate the low voltage side of the autotransformer through the series transformer **19**.

It will be appreciated that with this circuit as shown in Fig. 1, the line current flowing in any low voltage circuit connected across points **13—25** also passes through the series transformer secondary winding **21** so that winding **21** must be rated to carry this low voltage line current. Referring to Fig. 2 I have shown how, by means of my invention, a series transformer of much lower rating may be used to obtain the desired regulation of the low volt-

age side. Here I have illustrated an autotransformer of the type shown in Fig. 1, comprising a series winding 23—32 and a common winding 25—41. I have connected to the common winding a tap winding 41—24 which is situated on the same core as the common winding 25—41 and in effect extends the common winding to 24. A tap changing switch is connected in the tap winding circuit and I have illustrated it as a number of stationary contacts or taps 16 for engagement with a movable contact arm 27. Contact arm 27 is connected to ground potential as at 31 so that the high voltage side of the autotransformer extends between points 23 and 31. That portion of the tap winding between 24 and the contact arm 27 excites a primary winding 29 of a series transformer 28 (as shown). Alternatively the portion of the tap winding between 41 and 27 may be used to supply this variable excitation to primary winding 29. The regulated low voltage of the autotransformer extends between points 25 and 31.

In order that the potential of the high voltage side 23 to ground is not affected by the regulation of the low voltage between 25 and 31 I have broken at 32 the connection between the series and common windings and inserted the secondary winding 30 of series transformer 28 between points 32 and 25 so that winding 30 is in series with the autotransformer series winding 23—31. The low voltage lead connection is made at point 25 on the low voltage winding 25—31. Series transformer 28 is designed to have a 1:1 ratio and the relative polarities of its primary and secondary windings 29 and 30 are such as to prevent any change in the potential of point 32 with respect to point 31, or in the peak flux of the autotransformer core. Because of such arrangement of the series transformer windings, it will be seen that the regulated voltage tapped off the common winding 25—24 between 27 and 24 and applied to the primary winding 29, will appear as a compensating voltage across points 32—25 in the high voltage side of the autotransformer.

I have therefore provided for voltage regulation of the low voltage side of the autotransformer without changing either the potential of the high voltage side or the core flux, while requiring a lower rated series transformer than is required in presently accepted circuits. By using a 1:1 ratio series transformer and connecting its secondary winding in series with the series winding between the high voltage terminal and the low voltage terminal, I have compensated for the regulated voltage tapped from the common winding. In this circuit only a portion of the k.v.a. of regulation actually passes through the series transformer. The remainder is carried by the common winding to ground thereby bypassing the series transformer. Only that portion of the k.v.a. of regulation passing through the series transformer is transformed so that the series transformer need not be as highly rated as formerly. It will be seen from Fig. 2 that the series transformer carries the high voltage current while the series transformer in Fig. 1 must carry the low voltage current which of course is greater.

In my disclosure so far I have considered only a series transformer having a 1:1 ratio. While this isolates the switch from the line potential it does not allow a choice of the tap switch voltage. Consequently the voltage tapped off the low voltage winding of the autotransformer may not be the best operating voltage for the particular tap changing switch employed. Therefore I have shown in Fig. 3 a circuit in which I provide a series transformer having a different turns ratio in order to meet the best voltage operating characteristics of the tap changing switch employed. Here I have shown the same autotransformer with a series winding 23—32 and a common winding 25—41. A tap winding 42—24 is connected in series with the common winding through either of contacts 33 or 34 of a switch 37, which thus permits connection of either of points 42 or 24 respectively to end 41 of the common winding. In this way the regulated or tapped portion of the common winding may be used either to increase or decrease the low voltage of the autotransformer, depending on the position of this switch. Switch 37 is known to the art as a reversing switch and is used to double the effective range of regulation of the tap switch. Such a switch is usually provided together with the tap switch 27, although it was omitted for simplicity from Figs. 1 and 2.

The tap winding 42—24 connects through the movable contact arm 27 (which is engaged to any desired one of the taps 26), to the end 39 of the primary winding 29 of the series transformer 28. A tapped turn 35 of primary winding 29 is connected to ground 31 (while in the embodiments of Fig. 2 point 27 is connected directly to ground). The primary winding 29 is connected at 38 to point 41 of the common winding and the switch 37. The turns of the series transformer secondary winding 30 between 25 and 32 are equal in number to the turns of the portion 38—35 of the primary winding. In the circuit of Fig. 2, a 1:1 ratio series transformer is essential. In this circuit of Fig. 3 however, the tap winding 42—24 supplies variable excitation to the complete primary winding 38—39 of the series transformer, which is not restricted to have the same number of turns as the secondary 30. Again, as in Fig. 2, in this circuit only a portion of the k.v.a. of regulation actually passes through the series transformer. The remainder is carried by the tap winding to ground thereby bypassing the series transformer, which again carries in its secondary only the high voltage current. The 1:1 ratio between the turns of the series transformer winding of Fig. 2 is obtained in Fig. 3 between the secondary 30 and the portion 38—35 of the primary 29, so that the peak flux in the main autotransformer core is maintained constant. Consequently the circuit shown in Fig. 3 accomplishes the same results as that in Fig. 2 in that the series transformer carries only a portion of the low voltage current and the addition of the series transformer secondary in series with the autotransformer series winding compensates for the addition of a portion of the tap winding in series with the autotransformer common winding. At the same time a series transformer having a desired turns ratio may be used to replace the 1:1 ratio transformer in Fig. 2. By using the appropriate number of turns in designing the primary winding 38—39, the series transformer ratio provided is such as to allow the tap changing switch 27 to operate under its optimum voltage and current conditions.

An alternative form of Fig. 3 is shown in Fig. 4 wherein the series transformer ratio is again other than 1:1. In this instance additional turns 38–40 are added to the primary winding 29 in place of the turns 35—39 of Fig. 3. As in Figs. 2 and 3, this circuit provides that again only the high voltage current flows in the secondary winding 30 of the series transformer. End 41 of the common winding is again connected to point 38 on the primary such that the number of primary turns (38—35) to ground 31 equals the number of secondary turns 25–32. Thus regulation of the autotransformer low voltage is again provided for by the tap winding and the voltage applied across the contacts of tap switch 27 may be chosen in design by using the appropriate number of turns 38—40.

Fig. 5 shows another modification of Fig. 3 in which the basic circuit of my invention is adapted to a different connection of the switch 37. When used in this manner switch 37 is known to the art as a transfer switch. This transfer switch 37 connects point 42 on the tap winding 42—24 through its contacts 33 or 34 either to point 41 on the common winding 25—41, or to a tap point 43 provided on a common winding 25—41 to enable portion 41—43 thereof to be bypassed.

The voltage between 41 and 27 is used in the same way as before to regulate the low voltage of the auto-

transformer and turns 25—32 of the secondary compensate for this regulation as before.

In the embodiments of my invention thus far described I have shown secondary winding 30 connected between point 25 and the lower end 32 of the series winding. However secondary 30 may be connected in series with turns 23—32 of the series winding at any point intermediate points 23 and 32. This will increase the insulation level required of series transformer 28 although the current will still be reduced in the ratio of high voltage current to low voltage current.

Similarly, although I have shown the low voltage terminal and the end of the common winding as both connected at 25 to the secondary winding of the series transformer, it is also possible to modify the series transformer turns ratio by tapping the secondary winding. This can be done by separately connecting either the low voltage line or the end of the common winding, to a point intermediate the ends of the secondary winding 30. For reasons of insulation, however, it is considered easier to tap the primary winding as shown.

While I have described my invention with reference to a grounded neutral single phase autotransformer, it will be readily apparent that a three phase grounded Y autotransformer, or a transformer grounded through auxiliary equipment, may also utilize my invention. Consequently in the following claims where the term grounded neutral autotransformer is used, it will be understood that it is meant to cover both single phase and three phase autotransformers having reduced insulation level at the neutral end.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary contacts for cooperation wtih a movable contact of a tap changing switch, a series transformer rated at less than the k.v.a. of regulation of said autotransformer and having a primary winding and a secondary winding disposed on a core other than said autotransformer core, at least a portion of said primary winding being connected between ground and one end of said common winding, said primary winding being connected to receive variable excitation from said tap winding through said tap changing switch whereby the low voltage is regulated, and at least part of said secondary being connected in series with the turns of said series winding to carry the current thereof, the connections and turn ratio of said primary and secondary winding being arranged such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

2. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary contacts for cooperation with a movable contact of a tap changing switch, a series transformer having a primary winding and a secondary winding disposed on a core other than said autotransformer core, said primary winding being connected to receive variable excitation from said tap winding through said tap changing switch whereby the low voltage of the autotransformer is regulated, at least a portion of said primary winding being connected between ground and one end of said common winding, at least a portion of said secondary winding being connected in series with the turns of said series winding to carry the current thereof, the number of turns in said portions of primary and secondary windings being equal, said primary and secondary windings being connected such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

3. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding on said core for regulating the low voltage of said autotransformer, said tap winding having a number of stationary contacts for cooperation with a movable contact of a tap changing switch, a series transformer rated at less than the k.v.a. of regulation of said autotransformer and comprising at least a primary winding and a secondary winding both disposed on a core other than said autotransformer core, said tap changing switch supplying variable excitation from said tap winding to said primary winding, at least a portion of said primary winding having the same number of turns as said secondary winding, said portion of said primary winding being connected between ground and one end of said common winding, and said secondary winding being connected in series with the turns of said series winding so as to carry the current thereof, the relative polarities of said primary and secondary windings being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

4. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding on said core having a number of stationary contacts for cooperation with a movable contact of a tap changing switch, a series transformer rated at less than the k.v.a. of regulation of said autotransformer and comprising at least a primary winding and a secondary winding both disposed on a core other than said autotransformer core, said tap changing switch supplying variable excitation from said tap winding to said primary winding, at least a portion of said primary winding having the same number of turns as said secondary winding, the polarity of said secondary winding relative to said portion of the primary winding being such that when said primary portion is connected between ground and one end of said common winding and said secondary is connected between said series winding and the other end of said common winding so as to carry the current of said series winding the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

5. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding connected to one end of the common winding, said tap winding having a number of stationary contacts for cooperation with a movable contact of a grounded tap changing switch, a series transformer having its primary winding connected between the grounded tap changing switch and said one end of the common winding of the autotransformer while the secondary winding of said series transformer is connected between the other end of the common winding and the series winding of the autotransformer and has the same number of turns as said primary winding, the relative polarities of said primary and secondary windings being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

6. The combination of claim 5 in which said connection of said primary winding between ground and said one end of said common winding is made through said tap winding.

7. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary

contacts for cooperation with a movable contact of a grounded tap changing switch, a series transformer comprising at least a primary winding and a secondary winding both disposed on a core other than said autotransformer core, the turns of said primary and secondary windings respectively being in 1:1 ratio, said grounded switch supplying variable excitation from said tap winding to said primary winding, said primary winding being connected between ground and one end of said common winding, said secondary being connected between said series winding and the remaining end of said common winding, the relative polarities of said primary and secondary windings being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

8. The combination of claim 7 in which said connection of said primary winding between ground and said one end of said common winding is made through said tap winding.

9. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary contacts for cooperation with a movable contact of a tap changing switch, a series transformer comprising at least a primary winding and a secondary winding disposed on a core other than said autotransformer core, said switch supplying variable excitation from said tap winding to said primary, said secondary being connected between said series winding and one end of said common winding, at least a portion of said primary being connected between ground and the remaining end of said common winding such that the number of turns of said portion of primary winding equals the number of turns in the secondary winding, the relative polarities of said secondary winding and said portion of said primary winding being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

10. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding connected to one end of the common winding and having a number of stationary contacts for cooperation with a movable contact of an ungrounded tap changing switch, a series transformer having its primary winding connected between the ungrounded tap changing switch and said one end of the common winding of the autotransformer, said primary winding being grounded at an intermediate point, while the secondary winding of said series transformer is connected between the other end of the common winding and the series winding of the autotransformer and has the same number of turns as that portion of the primary winding which is connected between the said intermediate grounded point and that one end of the common winding which is connected to the tap winding, the relative polarities of said secondary winding and said portion of primary winding being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

11. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary contacts for cooperation with a movable contact of an ungrounded tap changing switch for regulating the low voltage of said autotransformer, a series transformer comprising a primary winding and a secondary winding both disposed on a core other than said autotransformer core, said ungrounded switch supplying variable excitation from said tap winding to said primary, said secondary winding being connected between one end of said common winding and said series winding, both said tap winding and said primary winding being connected to the remaining end of said common winding, one of the turns of said primary being connected to ground such that the number of turns in the portion of primary winding between said grounded turn and said remaining end of the common winding equals the number of turns in the secondary winding, the relative polarities of said secondary winding and said portion of primary winding being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

12. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding having a number of stationary contacts for cooperation with a movable contact of a grounded tap changing switch, a series transformer having its primary winding connected between the grounded tap changing switch and one end of the tap winding, said primary winding being connected at an intermediate point to one end of the common winding, while the secondary winding of said series transformer is connected between the other end of the common winding and the series winding of the autotransformer, said secondary having the same number of turns as that portion of the primary winding which is connected between the grounded switch and said intermediate point in the primary winding of the series transformer, the relative polarities of said secondary winding and said portion of primary winding being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

13. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary contacts for cooperation with a movable contact of a grounded tap changing switch, a series transformer comprising a primary winding and a secondary winding disposed on a core other than said autotransformer core, said grounded switch supplying variable excitation from said tap winding to said primary winding, said secondary winding being connected between one end of said common winding and said series winding, the remaining end of said common winding being connected to one of the turns of said primary such that the number of turns in the portion of primary winding between said turn and ground equals the number of turns in the secondary, the relative polarities of said secondary winding and said portion of primary winding being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

14. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding having a number of stationary contacts for cooperation with a movable contact of an ungrounded tap changing switch, a transfer switch for connecting said tap winding to said common winding, said transfer switch being capable of bypassing part of said common winding, a series transformer having its primary winding connected between the ungrounded tap changing switch and one end of said common winding, said primary winding being grounded at an intermediate point such that the number of turns in the portion of primary winding between said intermediate ground and said one end of the common winding is the same as the number of turns of said secondary winding, said secondary winding being connected between said series winding and the end of said common winding remote from said tap winding, the relative polarities of said secondary winding and said portion of primary winding being such that the values of peak core-

flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

15. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary contacts for cooperation with a movable contact of an ungrounded tap changing switch, a series transformer comprising a primary winding and a secondary winding both disposed on a core other than said autotransformer core, said ungrounded switch supplying variable excitation from said tap winding to said primary winding, said secondary winding being connected between one end of said common winding and said series winding, said primary winding being connected to the remaining end of said common winding, one of the turns of said primary winding being connected to ground such that the number of turns in the portion of primary winding between said grounded turn and said remaining end of the common winding equals the number of turns in the secondary winding, and a transfer switch capable of selectively connecting said tap winding to more than one point on said common winding, the relative polarities of said secondary winding and said portion of primary winding being such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

16. In a grounded neutral autotransformer having a core with a series winding and a common winding thereon, a circuit for regulating the low voltage of the autotransformer comprising, in combination, a tap winding disposed on said core and having a number of stationary contacts for cooperation with a movable contact of a tap changing switch, a series transformer rated at less than the k.v.a. of regulation of said autotransformer and having a primary winding and a secondary winding disposed on a core other than said autotransformer core, one point on said primary winding being connected to ground, the low voltage end of said common winding being connected to said point by way of at least a portion of one winding of said circuit, said primary winding being connected to receive variable excitation from said tap winding through said tap changing switch whereby the low voltage is regulated, and at least part of said secondary being connected in series with the turns of said series winding to carry the current thereof, the connections and turn ratio of said primary and secondary windings being arranged such that the values of peak core-flux and high voltage of the autotransformer are unaffected by said regulation of the low voltage.

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